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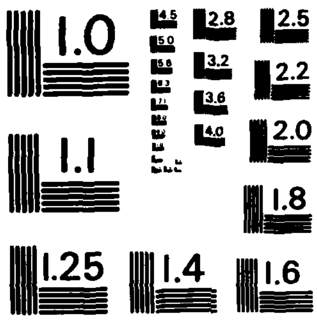

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FOREIGN TECHNOLOGY DIVISION

INTERNATIONAL AVIATION
(Selected Articles)

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APPLIED AERODYNAMICS

Tong /13

Fighter Aircraft: Recent progress in aerodynamics research predicts the development of highly efficient supersonic and highly maneuverable fighter planes. The joint effort of NASA's Langely Research Center and McDonnell Douglas has proven that earlier designs of the various large Aft-swept, delta flaps for reducing drag at supersonic speed can actually provide higher transonic maneuverability. The research results at Grumman, General Dynamics and Rockwell International have proven that the structure with forward swept wings has excellent maneuverability and low transonic drag. Grumman's forward-swept-wing demonstration aircraft X-29 (the first flight test will be in May 1984) is one of the most attractive projects in the past 25 years which oversteps the conventional aerodyamic concept for its unusual transonic wing shape as well as the variable curvature and the enhanced static stability. The optimization of the characteristics of X-29 at large angle of attack has created several designs such as edge flaps on rear fuselage with auxiliary vertical control surface, and small edge flaps on forward fuselage with slim forward fuselage.

Transport Aircrafts: The advanced three engine plane MD-100 of McDonnell Douglas employs a small winglet at the wingtip. Various airfoil designs are used to improve the rear payload. The rear fuselage has been modified to reduce the cruise resistance. The center of gravity is controlled to minimize the distributed resistance. In early studies by Boeing Co. on the employment of high flow ratio engines, the traditional nacelle arrangement had led to an extra long landing gear with high cost and weight. After applying computation aerodynamics on the aerodynamic characteristics of the closely installed nacelles under the wings, Boeing Aerospace Co. has created some new design principles, which allow the installation of the high flow ratio engine near the wings. The flight-test of Boeing 707 with CFM56 engine has demonstrated these principles. Afterward,

the nacelles of Boeing 737-300, 767, 757 were all installed near the wings.

V/STOL Aircrafts: X-wing aircraft has completed the 10 foot wind tunnel tests, and the suspension stall, transitional flight, rotary wing flight and fixed wing flight were simulated. Data on the states of height to advancement ratio (simulating stalling and starting of the rotor) and higher resonance controlled blow (controlled vibration and vibrating loading) was obtained. The Ames Research Center of NASA has extensively tested the typical X-wing design, providing data for the detailed design of the rotor to be used in the experimental rotary wing aircraft.

In 1983, a new airfoil, Configuration Control Wing (CCW), was developed. CCW can reduce the size, weight and cruise resistance and maintains the same climbing ability. The mono-element airfoil was developed by employing a very small rear edge radius (.009 chord length) with a thick super-critical airfoil.

Aerodynamic Techniques: More effective measuring techniques for aerodynamics are needed to improve the contemporary aircraft designs in order to extend the flight radius and release the static stability. Progress is made in the advanced surface element method capable of obtaining precise measurements of complicated structure force, moment of force, and maneuverability efficiency, full digital process program and the Euler's solution.

General Dynamics, McDonnell Douglas and Grumman Aerospace Corporation have cooperated with the Wright Aviation Laboratory of the Air Force and shown progress in the analysis of the interference of the closely coupled forward swept wings under transonic speeds. With the financial support of NASA, Boeing has shown promising progress in the current transonic "PanAir" method.

Northrop Corp., NASA Langley Center and University of Maryland have obtained interesting research results on the exhibition of the complicated flow pattern of the asymmetric release and breakdown of eddys under maximum angle of attack.

Many years of research efforts on the aerodynamics for the development of propulsion have obtained positive results. All experience and techniques have been condensed into a book, "Handbook on the aerodynamics, stability, and maneuverability of the V/STOL aircrafts", published by the Development Center of The Navy and Air Force.

FLIGHT TEST

Tong

NASA Dryden Flight Research Center and Ames Research Center have developed an important new flight test equipment. That is the Flight-Test Fixture (FTF) which can carry out fluid dynamic experiments in aerodynamics. It is installed on the vertical wing surface with small aspect ratio under a F-104. It has an experimental M number in the range of 0.4-2.0 and an experimental Re number higher than 40 x 10^6. It can also determine the micro- /14
increment of drag resistance on the test surfaces installed on both sides of the vertical wing. F-104/FTF is equipped with a cabin display navigation system for data display and transmission (which can transmit the telemetric data from the aircraft to the earth and send back to the aircraft after sorting and processing by a computer). The test flights for the Re number distribution of the fluid dynamics experiments, the dynamic pressure vs. M number curves in aerodynamic loading experiments as well as the equi-M number, equi-altitude sustained angle of attack turning in the performance test are all following unique tracks. The track accuracies of the FTF tests are: equi-Renold number distribution less than 5%, dynamic pressure distribution less than 1%, altitude deviation less than ± 100 ft in horizontal acceleration or deceleration flights.

Remarkable progress was made in data collection and processing of the flight tests. For example, Kohlman Research System, Inc. has developed an independent instrument which is easy to install. It can speedily collect flight data in order to provide verified stability and performance parameters for flight simulation. It has obtained and analyzed the data of whole flight curves for several types of aircrafts in less than a year (7 models of light jet aircrafts).

The main purpose of the flight test at icing condition is to understand the relation between the accumulation of ice and the measured physical properties of the cloud layer. NASA Lewis Research Center has established a set of generalized preliminary data for the icing wind tunnel test using a dual-fuselage aircraft equipped with instruments. The equipment includes the heated tail pipe for flight trace observation developed at Ohio State University. The flight data can indicate the actual loss of performance when the plane flys over a cloud layer of known icing characteristics. These data will be used for drawing up the inspection standards for icing. University of California has modeled the cloud behind an Air Force KC-135 air-refuelling aircraft to establish the relationship between natural icing and the artificial cloud produced by the air-refuelling aircraft. Other flight tests assessed some new equipment for preventing icing. The Army has tested an aerodynamic mask on the rotor blades of the UH-1 helicopter. In civil aviation, NASA Langely Center has tested a leading edge ethanol permeation system to prevent insect pollution of the wings.

Northrop Corp., F-20A "Tigershark" flight test plan has adopted a modern scattered data collection system. It combines program design (no rewiring) and multiple information channels (no large and cumbersome wire bundles). This aircraft has been used 289 times and accumulated 214 hours of flight time in 9 months. It covered all flight contours. There are more than 15 possible ways that the pilot might be used for demonstration.

An F-15 installed with advanced digital flight control system (designed for combining the engine, ignition control and navigation systems) has been delivered to Edward Air Force Base for flight test. The control system employs a parallel processing technique with microprocessors. The software is written in Pascal. This is the first time that this advanced computer language is used for an airplane flight control system. The advantages include reduced programming cost, ease of program modification and good economics.

Progress has been made in many flight test equipment. The test center of Edward Air Force Base is in the process of modernization. A total of 26,000 flight hours will be accomplished in 1985.

SCI System-Huntsville Co., is in the process of developing a standard instrument system for flight test. It is small, modular, and digital with multichannel transmitting devices and high data acquisition rate. In addition, a comprehensive aviation electronic system will allow the use of a laboratory computer to simulate tests and to calibrate various aviation electronic black boxes and to avoid or greatly reduce the time needed to troubleshoot in aviation electronic flight tests.

Federal Aviation Association has recognized the successful simultaneous development of 767 and 757 and granted the well known Kohler Award to Boeing Aerospace Co. This is the first time in history two aircrafts are certified within a year. Five 767 accomplished a total of 1,515 hours of flight tests from September 1981 to July 1982, and five 757 accomplished a total of 1,378 hours flight tests from February to December 1982.

In order to verify the structure improvement of F-16XL, Air Force and General Dynamics Co., carried out 369 test flights from July 1982 to May 1983. The test aircrafts were two modified F-16A; one had a single seat, the other had two seats.

The wings and the horizontal tails were modified to delta shape wings and the fuselage was extended an additional 56 inches. External attachments (AMRAAM, AIM-9L and MK-82) were suspended on the wings. The objective of the project was to improve the utilization of the aircraft, especially to improve the performance loss caused by the weapon attachments and to maintain the basic performance. It proved that the aircraft had the ability to avoid or overcome attacks from ground or air without releasing the bombs.

AV-8B aircraft had demonstrated its automatic vertical landing capability. Since there was no air speed input under such flight condition, a new computer controlled mechanism was used to test the stability of the aircraft.

Lockheed Tristar-1 research aircrafts were used in test flights to evaluate the flight quality under cruise condition when the margin of static stability was -0.03. This is part of the NASA program on high efficiency, energy saving aircrafts. The key point is the main pitch control system, including the command function which governs the pitch angle and speed of the pilot control and the input to serial pitch servo. The reduction in loading of the downward horizontal tail and the decrease in the cruise trim drag can save fuel by 4%.

The work on X-wings is continuing. After taking off vertically using 4 rotary blades, the blades will be firmly locked and form the X-wing. The aircraft is thrusted by two jet engines on regular flight. The air released from the nozzle flows to the edge of a selected blade to control the mobility. The performance of the rotor, effect of the downward flash of the rotor on the body structure and noise pollution have been evaluated using a half scale rotary tower model.

The Grumman's improved EA-6B test aircraft has finished the combat flight-test under simulated condition on an aircraft carrier at the Naval Weapons Center. The improvements include the changes in the interference system and better electronic warfare capability.

The research on XV-15 tilt-rotor plane continuously expanded its test flight contour.

The Army has carried out Rutan's (Rutan Long Ez) flight test for investigating a low cost observation aircraft with a canard layout.

V/STOL TECHNIQUE

Wei Ye /15

Since the Falkland Island War in 1982, V/STOL technique has obtained more attention and related projects are in full swing. The interest in V/STOL fighters has been changed to STOL in 1983. The United States and Britain held a meeting at Farnborough in June on "supersonic STOVL". Discussion was focused on the project of single engine STOVL fighter which should have M 1.6 ~ 1.8 supersonic capability for breaking through defense. There were four proposals for the propulsion equipment: plenumchamber combustion overthrust, ejector thrust promotion, tandem fans, and a remote lift enhancement system. Based on the results of the meeting, both countries are planning to establish four joint groups to select the most promising approach in 1988. NASA and the Canadian Department of Industry, Trade and commerce (DITC) are currently cooperating with General Dynamics and de Havilland Aircraft of Canada, Ltd., to modify a General Dynamics E-7 plane as a research aircraft with a thrust ejector.

The ejector is installed at the joint between the wing and the fuselage to provide the front climbing force and using thrust reversal to provide back climbing force. DITC has requested that the engine manufacturer provide a full scale aircraft to be tested in the 80 x 120 ft wind tunnel at Ames Research Center in 1987.

The joint project of NASA, U.S. Navy and industries on the development of the single cruise engine V/STOL fighter/attack aircraft is continuing at Ames Research Center. The projects on thrust vectoring, ejector thrust boost and tandem fans were investigated in phase 1,completed in 1982. Two models

were fabricated in phase 2 in 1983 and will be tested in the 12 ft and standardized wind tunnels at Ames Research Center. One of them is the McDonnell Douglas 9.2% reduced scale model which employs the design of thrust vectoring with plenumchamber combustion force enhancement. The model can be used for air flow test as well as for testing the jet blast effect, The other one is the General Dynamics ejector thrust boost/vectoring nozzle model (E-7). The 1/9 scale model was finished in February 1983 and the initial test on large angle of attack was completed in the 12 ft wind tunnel at Ames Research Center. Both models will be thoroughly tested in 1984.

There is another model with two advanced propulsion simulators which has finished the initial test in the 11 ft transonic wind tunnel at Ames Research Center. It is a typical STOL fighter design with two-dimensional nozzle and thrust vector control. The simulator is equipped with a single stage turbine, which drives a four stage compressor with 1,500 lb/sq inch compressed air. This new testing equipment can simultaneously simulate various current and advanced turbine fans, the air inlet and jet flow of a turbine engine.

General Dynamics has cooperated with Dynamics Engineering Co., in making the 1/6 scale free flying model of E-7. In 1983 the mosel will be tested in the 30 x 60 ft wind tunnel at Langely Research Center for developing the flight control system of the airplane.

In the British project for establishing a data bank for advanced V/STOL fighter planes, an old "Hawk" airplane was fitted with a "Pegasus-2" engine with plenumchamber combustion thrust booster for full scale investigation of the characteristics of the high thrust engine operating near the ground. During the test, the fuselage and engine assembly were suspended with a crane. The distance from the ground could be precisely controlled. Data to be measured includes the temperature increase of the inlet air, the change in temperature due to the recirculated hot steam and their effects on the performance of the engine.

It will also be used to investigate methods for reducing the intake of hot steam. The last phase will be the measurement of the erosion characteristics of the ground.

According to the tactical V/STOL technology development program, Naval Aviation System Command has contracted with General Electric, Pratt & Whitney, Rolls-Royce and Allison Gas Turbine to investigate Vought's tandem fan project, to evaluate the advantages and disadvantages, to provide comments for improvement, to identify the necessary key technologies and finally to draw up a five year technology development program. In addition, the project will include the investigation of various ejectors and the concept of supersonic vectoring thrust. NASA is cooperating with the Defense Department of Canada to investigate the general ejector projects using a regular ejector test station. The research on supersonic vectoring thrust will also be simultaneously carried out in McDonnell Douglas using the wind tunnel test with the 9.2% reduced scale model for thrust vectoring.

The tests on Grumman's two different scale models of deflection nacelle V/STOL are continuing at Ames Research Center. The static test of the large scale model has been completed in the field. The suspension characteristics with ground effect and the control efficiency with and without ground effect are being evaluated. In addition, a static test of the 11.4% reduced scale replica of the large model has been carried out in the 40 x 80 ft wind tunnel with floor. The model was powered by two TF34 simulators driven by compressed air. The experiments included the determination of various parameters and the effects of a deflecting nacelle.

Additional small model tests will be carried out in 1984. The characteristics at large angle of attack will be carried out in the 12 ft wind tunnel at Ames Research Center. The characteristics of low speed taking-off and landing will be investigated in the 4 x 7 M low speed wind tunnel at the Langely Center.

In order to investigate the control/display funtions of the plane on suspension and on board, simulation tests of the single engine AV-8B aircraft model have been carried out at Ames Research Center using the vertical motion simulator equipped with a graphic visual display system using a four window screen display computer. Twelve control systems and 7 display systems have been evaluated. The results indicate that the horizontal display is very important at serious sea conditions. Translational velocity command is the most effective control technique. With attention on horizontal display signals, the position command by the automatic nozzle push rod and the vertical buffer is acceptable even at No. 6 sea condition. On air suspension, the push rod can provide a small displacement for the nozzle. Presently, format of horizontal display and pilot control are being improved based on test results.

A "Hawk" research aircraft was employed at RAE-Bedford at the end of 1982 for evaluating velocity control of automatic nozzle push rod and the format of the horizontal display. Additional experiments were carried out in the winter of 1983.

NASA will initiate a flight research project using YAV-8B to demonstrate the flight control and display as well as to show the results of simulation test of the navigation and guidance technology in the beginning of 1984.

More research activities on rotary wings were carried out in 1983. In the joint military project JVX, Naval Aviation System Command has replaced Army as the leader and issued an RFP to the industries on January 17 for a 23 months project for the initial engineering design phase (includes various wind tunnel tests, compromised research and analyses as well as computer simulations). The RFP defined that JVX should be a self-deployment, multi-mission V/STOL aircraft, capable to carry out daily flights from a simple air base or on an aircraft carrier. The missions include search and rescue during Navy aerial combats, special flight missions for the Air Force and

assault missions for Marines on the sea or on the ground. The defined performance specifications include: surface elevation 30,000 ft, dash speed 275-300 nautical miles/hour, self-deployment flight radius 2,100 nautical miles.

On February 17, 1983, only the working groups at Bell Helicopter Textron, Inc., and Boeing Vertol Co., proposed a tilt-rotor vehicle similar to XV-15 with a weight about three times that of the XV-15. After examination, the contract on the initial engineering design phase was signed in April.

The Army's LHX project is progressing in an accelerating manner. The project is to provide a group of light scout/attack and multi-purpose helicopters to replace the current UH-1, AH-1, OH-6, and OH-58 light helicopters. The Army is currently re-organizing the project to assure progress to produce the scout/attack models by 1990 and to accomplish the initial combat capability by 1992. One of the objectives of the project is to apply various new technologies to aircrafts, which include composite materials, light transmission parts, supersonic integrated circuits, automatic target recognition and voice control, etc. Regarding target aiming and control, a single pilot design can be realized by applying the current design of the Army's helicopters.

A flutter test and a flight test of the rotary system research aircraft (RSRA) were carried out at Ames Research Center in 1983. The rotor was on full load during the flight which made the wings to take most of the load. After those tests and isolated system tests, the aircraft will be retrofitted with an X-wing for study by Sikorsky Aircraft Corp.

Optimistically, the first flight test of the RSRA/X-wing project will be carried out in 1985. Presently there are many problems in aerodynamics, structure integrity (includes vibration, rigidity, materials and processing methods) as well as stability and maneuverability which have to be solved.

AIR JET PROPULSION TECHNOLOGY

The development of high fuel efficiency engines and their improved models for civil aviation continues to make progress. Based on the NASA sponsored E^3 energy-saving engine project, General Electric (GE) tested an integrated engine assembly comprised of a core engine and a series of low pressure rotors. Pratt and Whitney (P&W) tested a series of advanced parts for the core engine. The development of the high fuel-efficient, high speed turbo-fan propulsion installation to be used in future transports also achieved good results. In military aviation, the verification of the high performance core engine technology, funded by the United States Air Force (USAF), progressed successfully. The project to verify the prototype 5000 axial horse-power engine, funded by the United States Army (Army), has already started. The dual-function nozzle exit for high mobility airplanes was certified. Recently, digital electronic controls for engines were employed in civil as well as military aircrafts to greatly improve the performance and reliability of engines.

TURBO-ENGINES

The application of high flow ratio CFM56-2 engine series is expanding. In March, a "DC8 super 70" airplane installed with four CFM56-2 engines completed a non-stop flight from Cairo to Los Angeles in 15 hours and 46 minutes for a distance of 13,220 kilometers. The remianing fuel was still enough for another 1,380 kilometers. The CFM56-3 engine which was scheduled to be installed on Boeing 737-300 twin-engine passenger planes, completed a 150-hour engine-test-stand test. The test proved engine endurance at extreme temperatures. The CFM56-3 engine was selected for the A-320 airplane.

The flight certificate for the PW2037 engine with a thrust of 16,780 kilogram developed for Boeing 757 passenger planes was estimated to be issued in December of 1983. Some of the accomplishments from the NASA/PW E^3 project were adopted in the PW 2037 engine. Compared with similar engines

with the same thrust, the PW2037 engine consumes 8% less fuel.

The flight certificate for the high flow CF6-80C2 engine is expected to be issued by 1985. Some of the research accomplishments from the NASA/GE E^3 project were adopted.

Based on the NASA high speed propeller project, an auxiliary propeller was used in flight tests to investigate the propeller noise characteristics. This research also included the /17
study of a reverse rotating propeller model.

The Armed Forces started two important projects for new turbo-engine development: the 5000 axial horse power class Modern Technology Development Engine (MTDE) project, and the Joint Fighter-Engine (JFE) project. Compared with current engines, JFE greatly increased the thrust-weight ratio and the endurance at supersonic speed. Both GE and P&W were awarded MTDE prototype engine contracts. MTDE engines were designed to be used on five different military aircrafts, including the CH-47 helicopter for the Army, and the land-based anti-submarine airplane P-3 for the U.S. Navy (USN).

The PW1128 turbo engine, an improved F100, (to be used on advanced F-15 and F-16 aircraft) successfully passed the flight test. The PW1120 turbo engine, another derivative of the F100 engine, with a 9070 kilogram thrust has completed approximately 500 hours of sea-level and high altitude test. It was scheduled for flight tests at the beginning of 1984, and expected to pass the product certification test before the end of 1986.

The F110 augmented turbo-fan engine (i.e., F101DFE) completed the flight test on F-16XL experimental plane. The hot section life index (5,004 TAC cycle, equivalent to 2500 flying hours) was also verified.

AVCO/Lycoming was in the process of improving the PLT34 engine. This engine employed single crystal turbine blades, metal temperature monitoring device for the turbine blade, ceramic coating on the combustion chamber wall, and digital electronic control device with an optical fiber data transmission circuit.

VERIFICATION OF ADVANCED TECHNOLOGIES

The NASA/GE E^3 energy-efficient engine underwent a performance test on an open-air test stand. The test results met and even surpassed the required specification. This indicated that the measures adopted by GE and P&W to decrease fuel consumption by 15% (as compared with CF6-50C and JT9D-7A) were feasible. Based upon recent research, it was assumed that fuel consumption could be further reduced by another 15% if the compression ratio, flow ratio, and part-assembly efficiency as well as turbine inlet temperature were all increased.

The fact that GE successfully completed the preliminary test of GE29 gas generator was the most important new engine test since the operation of the GE1 gas generator in the mid 1960's. The features of the GE29 gas generator are: five stage variable geometric high flow compressor, lightweight, high temperature, ceramic tile constructed combustion chamber burner, and single stage variable turbine cooled by air film (cooling air volume could be adjusted). The major interesting point of GE29 is that it has made it possible to drastically increase the unit thrust. Thus, the augment combustion chamber could be eliminated. The variable geometry feature was that the thrust could be instantaneously adjusted without changing engine speed. It is beneficial to increase engine life and decrease fuel consumption during cruising. Experimental results of the new technology showed that as compared with current engine, P&W's new "flow path core engine" (to be used in JFE turbo engine) had the possibility to increase the thrust-weight ratio by 25% to reduce fuel consumption by 7%, to improve the engine durability and reliability, and to cut down the number of parts. Hence, eventually the total cost during the engine life could be reduced by 25%. Through this series of experiments, the major components of the advanced turbine engine gas generator (ATEDD) project were evaluated. These components are: five stage wide blade chord high flow compressor (the compression ratio, efficiency, and stall limit were similar to

those of JFE), floating wall combustion chamber (capable of eliminating the frequently encountered low cycle fatigue failure in present combustion chambers), and high temperature, high pressure single stage turbines (its requirements are more strict than those of JFE).

THE UNITIZATION OF ENGINE-FUSELAGE

Based on the requirements of the USAF contracts, Grumman completed a major wind tunnel experiments project, aimed at evaluating several different proposed advanced nozzles. In the 16-foot transonic propulsion wind tunnel in the Arnold Engineering Development Center, the high speed air propulsion performance characteristics of four proposed nozzles were evaluated. The four nozzle plans are: an adjustable thrust vector axially symmetric structure (also as a base line) and contracting-expanding three other asymmetric expansion oblique plate structures. During testing, they were installed on a standard short take-off and landing (STOL) tactical fighter.

Upon the request of USAF, Grumman used a F100 engine with a dual element contracting-expanding nozzle to verify the instantaneous and steady state operating condition of the engine and its nozzle under reverse thrust, deflected thrust, as well as other combination conditions. During reverse thrusting, the exit cone would switch from the idling state to the medium thrust state. While during thrust deflection, the exit cone would transfer from the idling state to the maximum power state. At the maximum power state, the engine thrust could be deflected by 20°.

COMPRESSORS AND FANS

GE tested two types of multi-stage compressors. They were: the GE27 axial-flow (five stage)-centrifugal (one stage) model of the Army MTDE, and the NASA E^3 straight axial flow model. Compression ratios were 20 and 23, respectively. So far, these two had the highest compression ratio as compared with other single rotor models. It was proven in an engine that these

two compressors had good efficiency in a complete working range including starting.

Based on a research project funded by the USAF, Wright Aviation Lab designed a three stage experimental compressor (TESCOM) whose blade tip speed and wheel to hub ratio reached a high standard. A reverse rotation design was adopted for the first stage of the compressor to increase the flow rate. Coupled with the sweep-back design of the leading edge, the shock wave loss was controlled. Within a larger rotating speed range the maximum adiabatic efficiency of the first stage exceeded 88%. The working linear compression ratio approached 2.3 when the blade tip speed was 381 m/sec. This experiment indicated that at the reverse core compressor rotating speed, it has good working characteristics and very high stage compression rise.

Upon the request of the USAF, GE developed a new analytical tool to estimate the damage of the compressor and fan blades caused by foreign objects during take-off and landing. The design criteria for blade damages were obtained by combining the finite element instantaneous structure response model and the loading model of the bird collision and icing on the first stage fan and compressor. In addition to the rotating impact, /18
tests were conducted on blade shaped specimens to verify the model. Test results were in good agreement with the calculated results.

COMBUSTION

In view of the requirements on fuel economy, adaptability, and system characteristics in the aeronautic propulsion industry, the design and the operating conditions of the combustion chamber are undergoing large changes. This means that if the traditional cut-and-trial method was used, the development cost would have been unacceptable. Based upon reason and the increasing applications of the computer assisted design in system analysis, industries, government departments, and higher learning institutions, are urged to develop analytical models for different combustion processes.

A detail calculation of the complex turbulence combustion flow becomes more feasible because of improved computer calculating speed and memory size. The main problem is how to rationally analyze the mixing and reaction processes of a turbulent flow. The practical analytical method involves the basic turbulence models based on empirical deductions. However, the universal applicability of these models have not yet been verified. Furthermore, in order to deal with the actual problem of a combustion chanber, the uncertainties of a turbulent flow affected by factors such as reaction, radiation and heat dispersion have to be understood. Based on the engine hot section technology project (HSTP) supported by NASA, GE, P&W and Allison were conducting research on these problems.

Great progress has been made in the development of the computer program for three-dimension non-steady state flow. These programs were developed to simulate the original physical properties of the combustion turbulent flow's large scale characteristics without relying on empirical models. The active research field is how to practically utilize this method to solve the small scale problems of a combustion flow.

The fast development of the optical diagnostic method improved the non-contact rapid response instrumentation used in a hostile, multi-phase turbulent combustion flow to support the modeling work. Most of these instruments were constructed based on the principle of laser scattering. New development in the 3-dimension non-steady state flow also promoted the development of the method to monitor simultaneously the distribution along a line, a plane and a specific volume. Progress was also made in holographic imaging to determine the parametric distribution in a gas flow.

Problems associated with increasing smoke particle concentration will be aggravated by using low grade fuel and synthetic fuel as well as by higher cycle pressure and temperature parameters. Researchers have already been alerted about the origin of smoke formation. Progress was made in the research on the oxidation of the smoke particles, as well as in the

research on the effect of fuel type, operating condition and additive on the formation of smoke particles in the flames and the combustion chamber.

Some results from the research on the nucleation of smoke particles under turbulent conditions and heterogeneous reaction were still difficult to interpret. Therefore, extensive investigations of smoke particles will continue.

Researchers were interested in utilizing carbon black and boron as the components of fuel for air jet propulsion of long range guided missiles because of their high specific volumetric heat volume. However, the difficulties in ignition, combustion and coacervation along with the condensation problem of boron caused a lot of problems in combustion chamber design. When a carbon black and boron containing fuel is in a colloidal state, there are stability and atomization problems. Therefore, these phenomena should be understood in the field. In addition, the effect of system parameters should also be made aware of.

Allison and P&W cooperatively began to verify the application of perforated clad plates in air cooled burners. Compared with the conventional air-film cooling method, the perforated clad structure could reduce the cooling air volume by 60%.

GROUND TEST

In the past year, progress and achievements were made in the ground testing of jet propulsion systems.

Five NATO nations, U.S., Canada, U.K., France, and Turkey, agreed to participate in the J57 Unified Test Engine (UTE) project of the Advisory Group of Aviation Research and Development (AGARD). The purposes of this international project were: to investigate and eliminate the differences in ground testing technologies for jet turbo engines in the west, to improve the turbo engine testing technology, and to formulate a universal standard for engine certification. Among seven testing facilities in this project, three were located in the U.S. They were the USAF Arnold Engineering Development Center, the NASA Lewis Research Center and the Naval Aviation Propulsion Center (NAPC), respectively.

The Compressor Research Facility (CRF) of the Air Force Aviation Propulsion Laboratory (AFAPL) was able to test full size compressors of gas turbo engines. It includes a 30,000 horse power variable speed electric transmission device, an experimental compressor, and a data collecting system capable of sampling 50,000 times per second. CRF was controlled by a network of seven minicomputers. The data was collected and fed into an IBM 4341 for online real time analysis. Four out of the seven minicomputers were connected to a common memory for real time control of the CRF, the transmission device and the experimental compressor. The control cycle was ten milli-seconds. The operating condition of the CRF was displayed on eight color monitors on a real time basis through the graphic language input. An eighth minicomputer was used to simulate the CRF in order to test the software and train personnel. The low speed, high density flow zone and the high speed, low density flow zone of CRF were evaluated with the compressors of J58 amd J85 engines, respectively. The high blade speed compressor made by GE and cone compressor of the F100 engine made by P&W were prepared to be tested in this facility.

The three engine test stands of Lockheed at Branfield, each installed with a dual direction thrust measuring system, were capable of testing turbo engines and turbo-fan engines over a large range of thrust and reverse thrust. They could also conduct certification tests of aircraft engine parts according to FAA specifications.

The 16-foot propulsion wind tunnel in the Air Force Arnold Engineering Development Center is undergoing design modification. The aims of this modification are: improving flow quality, decreasing the temperature non-uniformity of the test section, and enlarging the area of pressure augmentator to reduce energy /19
consumption of the propulsion tunnel. The engines under test at Arnold Engineering Development Center are listed as follows: F101 turbo-fan engine (to evaluate different design modifications before production, and to test the different construction types of the J-2 engine testing facility), PW1120 augmentated turbo

jet engine, F100-PW-200 turbo-fan engine (high altitude simulation test in progress, altitude: sea level to 18,300 meters, Mach number: 2.3, purpose: to evaluate the engine digital electronic control system), F110 augmented turbo-fan engine (operation at different altitudes in progress, purpose: to evaluate the engine after-burner and the control system), and F3-30 turbo-fan engine for XT-4 subsonic twin engine trainer of Self-Defense Air Force of Japan.

THE SUCCESSFUL DEVELOPMENT OF TARGET TRACKING DISPLAY SYSTEM /46

Zhang Kehan Zhou Ziqian

The ultimate analysis of the flight quality of a pilot aircraft is to study the close loop characteristics between the pilot and the aircraft. Even the open loop index of the flight quality standards are specified according to the pilot's assessment of the close loop characteristics of the man-machine relationship. Due to the limitation of the test flight equipment, it was not possible to establish an organic relation between the pilot's qualitative evaluation and the quantitative measurements of airplane parameters in the study of flight quality. This is because the pilot's qualitative evaluation is a critique of one specific flying mission, while the measurement of the airplane parameters is based on the airplane response of a typical maneuvering. Therefore, it is difficult to establish a set of unified flight quality criteria based on the limited relationship between the test flight conclusions and measured parameters.

The development of the domestic target tracking display system introduced in this paper was aimed at resolving the need to establish unified criteria for the pilot-plane close loop characteristics. It was certified in September 1983. The system mainly consists of the following components: display unit, hitting efficiency computer, pseudo-random signal generator, and attitude gyroscopes (See Figure 1).

DISPLAY UNIT

Two graphic images are exhibited on the screen of the display unit with a 7" picture tube. The piloted airplane appears on the screen as a line segment with a bright spot in the center. The length of the line segment can be adjusted according to the wing span. The up and down, left and right, and inclined motions of the aircraft image represent the pitching, the yawing, and the rolling maneuvers of the piloted airplane, respectively.

The other graphic image is a ring. It represents the distance between the target-plane and the piloted airplane. The target ring, controlled by a random perturbation signal, moves in the up-down and left-right directions on the screens of the display unit.

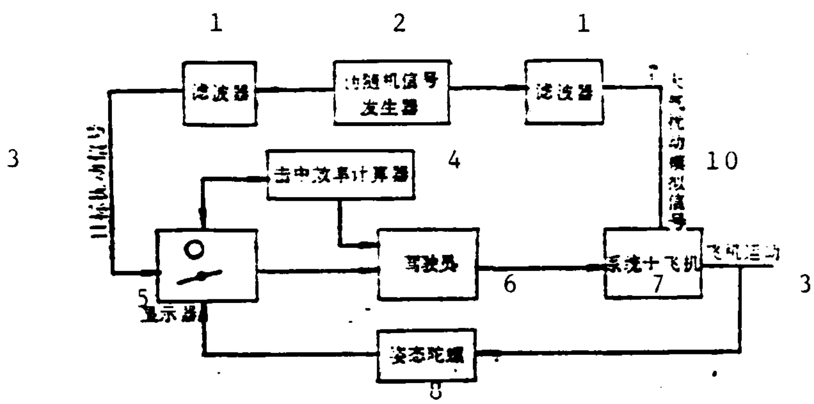

Figure 1. Function Diagram of the Target Tracking Display System

1. wave filter
2. pseudo-random signal generator
3. target perturbation signal
4. hitting efficiency computer
5. display unit
6. pilot
7. system + airplane
8. attitude gyroscopes
9. motion of airplane
10. atmosphere disturbance simulation signal

When a pulse signal is sent to the display unit within 0.7 sec. after the geometrical center of airplane image moves into the target ring, the ring image will severely be defocused and glow brightly. This indicates that the target is hit.

The display unit is installed directly in front of the pilot's vision.

HITTING EFFICIENCY COMPUTER

The calculator determines the correct hitting record based on the difference between the parameters of the two images. It also calculates the tracking efficiency and displays the number of hits and the tracking efficiency by means of one or two digit numbers.

(1) Determination of Scoring: After the airplane image enters the target ring for "t" seconds (a ring stabilization time can be assumed), the pilot will push the firing button. Then the calculator will deliver a pulse signal to the display unit indicating that the target is hit. When the aforementioned two conditions are not met, the calculator will not deliver the pulse signal. The "t" value of the scoring conditions in the calculator can be adjusted in order to simulate different ring stabilization periods.

(2) Calculation of the Tracking Efficiency: The tracking efficiency is an indicator to measure the skill of the pilot's tracking capability. Figure 2 shows the diagram for calculating the tracking efficiency.

The tracking efficiency is calculated according to the following equation:

$$\eta = \frac{\int_0^T (a^2 - \varepsilon^2)\,dt}{\int_0^T d^2\,dt}$$

Where:
$$\alpha^2 = A_X^2 + A_Y^2 \quad (\alpha = OA)$$
$$\varepsilon^2 = \varepsilon_X^2 + \varepsilon_Y^2 \quad (\varepsilon = AB)$$
$$\varepsilon_X = A_X - B_X$$
$$\varepsilon_Y = A_Y - B_Y$$

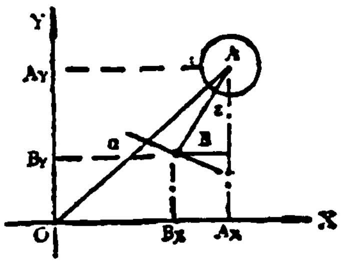

Figure 2. Tracking Efficiency Calculation

"T" represents the testing cycle, which is selected according to different testing circumstances: T = 30, 60, 180, and 240 seconds.

PSEUDO-RANDOM SIGNAL GENERATOR

The generator produces three independent series of random signals. Two of them are transmitted to the display unit as the perturbed motion signal of the target ring. The other one is transmitted to the airplane to simulate the disturbance of the atmosphere (Figure 1). The basic units and their functions of the generator are shown in Figure 3:

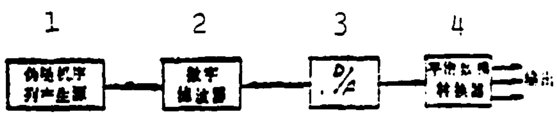

Figure 3. The Components and their Function of Pseudo-random Signal Generator

1. Pseudo-random array source
2. Digital filter
3. Digital-to-analog wave smoothing converter
4. Outlet

The pseudo-random array source produces a uniform density white noise array within a wide frequency range. This series, through the operation of a digital wave filter is changed into a slow, narrow (determined by the different combination of the particular function transmitted through the wave filter) digital random array. Through a digital-to-analog converter, this array is transformed into a continuous step-ladder waveform. Finally, this wave is further transformed into an ideal smooth random stimulation signal through a smoothing step.

Both the generation of the pseudo-random signal and the operation of the digital filter are conducted by a single board computer. The digital-to-analog converter and the smoothing circuit are all installed on one board. The complete calculation program and the filter coefficient of different combinations are all fixed in a ROM.

Based on the different characteristics of the filter and the different tracking patterns, the pseudo-random signal generator can form twelve different combinations. Proper conditions can be selected according to the experimental tracking mission.

ATTITUDE GYROSCOPES

Vertical gyroscope: TPW-1A reflects the changes of pitching angle θ and the rolling angle γ .

Navigation gyroscope: TH-5A reflects the change $\Delta\phi$ of the flying direction angle ϕ.

During the tracking experiment, the attitude gyroscopes transform the flying altitude into a voltage signal and sends it to the display unit to move the airplane image in three degrees of freedom.

The target tracking display system is an important equipment for studying the close-loop characteristics of the pilot-airplane relationship. Its functions are listed as follows:

(1) It can provide two different tracking patterns to the pilot. They are the pursuit-tracking pattern, and the compensation tracking pattern. The pursuit-tracking pattern supplies

the signals of two independent operations - airplane and target to the pilot. The pilot's mission is to control the airplane to follow the target in such a way that he should try hard to match the two images all the time. In compensated tracking, the information on the relative motion between the target and the airplane is constantly shown to the pilot. In this pattern, the target ring is kept steady, while the airplane image is in a disturbance motion. The airplane motion controlled by the pilot is the difference between these two images. From the flight mechanics point of view, these two patterns represent two different tracking missions. The pilots, when conducting these two missions, will have two different mathematical models.

(2) It can conduct the research of the three independent axes separately. During the three-axis tracking, the target moves in the X-Y direction and the airplane is maneuvered according to the pitching, yawing, and rolling axes, respectively. Thereby, the combined tracking characteristics of the pilot-airplane close loop system for the three airplane axes can be evaluated. For single axis tracking research, both the target and the airplane are in a single degree-of-freedom motion. Thus, the pilot-airplane close loop characteristics of any one axis can be evaluated.

(3) This system can show the tracking efficiency and number of scoring to the pilot at the proper time. Both parameters are supplemental indicators of the pilot-airplane close loop characteristics. They can reflect the degree of succession of the tracking characteristics as well as impel the pilot to concentrate in order to accomplish a better combat record.

(4) Through a servo-steering mechanism, this system can supply the artificial atmosphere disturbance signal to the flight stimulator.

The features of studying the flight characteristics of the pilot-airplane close loop relationship with this system are listed as follows:

(1) Compared with the method using a fixed ring to track a real target plane, and the gun camera and film to judge the relative position between the airplane and the target, this system has an apparent economical benefit because the actual flight of the target plane is eliminated. Besides, it is difficult for the pilot to predict the movement of the target plane because of its random nature. However, the general pattern is regular, therefore, it provides better repeatability for test flight. In addition, this system makes the coordination and the data recording easy. Therefore, it improves the test flight quality.

(2) Compared with a modified instrumentation tracking system, this system has better characteristics and more functions.

(3) This system is worthwhile promoting. It becomes not only a special standard equipment for the airplane, but also can be used in ground flight simulator and in different airplane models to evaluate their flight quality.

Owing to the fact that the target tracking display system has the aforementioned functions and advantages, it will have an important effect on the future development of aviation technology.

INDIA PLANNING TO DEVELOP NEW LIGHT COMBAT AIRPLANE

India has a plan to develop a supersonic light combat aircraft (LCA). The plan has been approved by the government. It is supervised by the Indian Defense Ministry, India National Aviation Research Institute; the Indonisian Aviation Company also participates in the work.

The development of the LCA was conducted by the IAC in collaboration with a foreign company. However, the sales and the customers are mainly concentrated in India. It is planned that the feasibility study will be done in May. The imported technologies include: graphics fiber composite material, electronic transducer technology for main control, signal and display equipment, etc.

France promised to transfer the advanced technology of "Mirage 2000". India hoped that they could participate in the entire development work of the new airplane.

LCA is named as P106. It will adopt a delta wing with duck type layout. The gross weight is 9,072 to 11,340 kilograms and the maximum speed is approximately M2.

Forty percent of the airplane structural weight will be made of composite materials/ The engine is the developmental type RB199 engine with thrust augmentation device.

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